CHAPTER 7

Perspectives on Implementation

A substantial financial investment is being made in the Columbia River basin to recover listed chinook, coho, steelhead, and chum. How much of this investment should be made in the estuary? How much do the estuary, plume, and nearshore environments contribute to the survival of upstream ESUs, and is recovery of upstream ESUs possible without a healthier estuary ecosystem? If not, what does the information in Chapters 3, 4, and 5 tell us about which management actions to implement in the estuary?

Chapter 7 explores issues related to the selection of management actions to be implemented in the estuary and how those choices will shape future conditions for salmonids in the estuary, plume, and nearshore.

Putting the Estuary in Context

This recovery plan module reflects current scientific understanding that the Columbia River estuary, plume, and nearshore provide habitat that wild salmonids need to complete their life cycles. Historically, juveniles from hundreds of distinct salmonid populations, at various life history stages, used the estuary for refuge and rearing as they prepared physiologically for life in the ocean. Over evolutionary time populations developed life history strategies in which juveniles from different populations staggered their use of the estuary throughout the year, exploiting estuarine habitats in different ways for different lengths of time. Although the estuary posed risks to juvenile salmonids, the diversity in life history strategies allowed salmon and steelhead to take maximum advantage of estuarine resources, which offered tremendous opportunities for refuge and growth. Unlike an upstream tributary, through the year the estuary provided habitat for all of the salmonid populations in the Columbia River basin during a critical stage in their life cycles.

Over the last 200 years the ability of the Columbia River estuary to meet the needs of salmon and steelhead has been seriously compromised. There is no question about the extent of changes in the estuary: the timing, magnitude, and duration of flows do not resemble those of historical flows, access to the estuary floodplain has been virtually eliminated, sediment transport processes that depend on flows and upstream sediment sources are radically different than they were historically, water quality has degraded as a result of contamination, temperatures are approaching and sometimes exceeding lethal limits, and there have been fundamental changes at the base of the estuarine food web, with associated alterations in inter- and intra-species relationships. Given these changes, the current mortality rate for some Columbia River ESUs in the estuary may exceed 50 percent (Lower Columbia Fish Recovery Board 2004).

A central premise of this recovery plan module is that although the estuary ecosystem is degraded, it can be improved, and that a healthier estuary ecosystem would contribute meaningfully to the basinwide recovery of ESA-listed salmonids.

Factors That Influence Decision Making

Decisions about implementation would be easy if protecting and restoring salmonids were the only consideration. However, as much as we value healthy native fish runs, as a society we also value a stable economy, financial opportunity for individuals and businesses, public safety, and property rights. These values will play into decisions about which management actions to implement, as will the three factors used to evaluate the management actions in Chapter 5: cost, constraints, and potential benefits to salmonids.

Also affecting choices about implementation is scientific uncertainty. Although fisheries science has matured over the last 100 years, how salmonids interact in complex ecosystems is not well understood, and this is especially true in the estuary, plume, and nearshore. Yet we cannot wait until uncertainty has been eliminated before taking action. In the face of scientific uncertainty, then, decisions about implementing management actions will have to be made using the most current scientific information available, combined with best professional judgment. Historically, it has been a mix of science and policy choices that have guided decisions that affected the estuary; it is likely that these same forces will also determine the effectiveness of science-driven recovery efforts.

Significance of Constraints to Implementation

Not a single management action identified in Table 5-1 will be easy to implement. In one way or another, implementation of each of the 23 actions is constrained, in some cases greatly. For example, implementation of CRE-4, "Adjust the timing, magnitude, and frequency of flows," is constrained by international treaties, the need for flood control, irrigation requirements, upstream fish issues, and electrical generation. Given these constraints, returning to historical flows—or even something close to historical flows—is impossible. Yet CRE-4 is proposed as a management action because it might offer significant benefits to salmonids even if its implementation were incremental.

Understanding the nature and magnitude of constraints to the implementation of management actions is important for several reasons. First, it grounds the actions in the real world and tempers expectations for results. Second, it provides insights into the level of effort that would be required for an action to have a sizable impact on salmonid populations. Third and most important, it reveals that every proposed action in this recovery plan module has significant obstacles to implementation.

Because it will be difficult to implement any single action fully and gain all of its potential benefit to salmonids, it will be important to implement a relatively large number of the proposed management actions. In other words, if each management action in the estuary has significant constraints, it may take partial implementation of all or most of the actions to improve the health of the estuary ecosystem to the point that the ecosystem provides the benefits that salmonids need to recover.

To illustrate the relative constraints of different actions, Table 7-1 presents management actions by degree of constraint to implementation, in descending order.

TABLE 7-1
Management Actions Sorted by Degree of Constraint

#	Action	Degree of Constraint
CRE-03	Establish minimum instream flows.	5
CRE-04	Adjust the timing, magnitude, and frequency of flows.	5
CRE-05	Mitigate entrapment of fine sediment in reservoirs.	5
CRE-18	Reduce shad abundance.	5
CRE-19	Prevent invertebrate introductions.	5
CRE-14	Reduce predation by pinnipeds.	4
CRE-15	Reduce noxious weeds.	4
CRE-09	Protect remaining high-quality off-channel habitat.	4
CRE-17	Redistribute cormorants.	4
CRE-21	Identify and reduce sources of pollutants.	4
CRE-20	Implement pesticide/fertilizer BMPs.	4
CRE-02	Operate the hydrosystem to reduce reservoir heating.	3
CRE-10	Breach or lower dikes and levees.	3
CRE-12	Reduce vessel wake stranding.	3
CRE-22	Monitor and restore contaminated sites.	3
CRE-11	Reduce over-water structures.	3
CRE-01	Protect/restore riparian areas.	3
CRE-06	Use dredged materials beneficially.	3
CRE-16	Redistribute Caspian terns.	2
CRE-07	Reduce entrainment/habitat effects of dredging.	2
CRE-13	Manage pikeminnow and other piscivorous fish.	2
CRE-23	Implement stormwater BMPs.	2
CRE-08	Remove pilings and pile dikes.	2

Another useful table when considering implementation constraints is Table 5-3, which shows the differences in potential benefit to salmonids if implementation of actions is unconstrained, which is unrealistic, versus constrained, which represents what may actually be possible. However, although Table 5-3 demonstrates the size of the gap between unconstrained and constrained implementation of actions, it does not adequately characterize the magnitude of response that might be expected from constrained implementation. The next section of this document is intended to help show the potential benefit from constrained implementation of actions.

Management Actions Offering the Greatest Survival Benefits

If we were to increase our financial investment in restoration of the Columbia River estuary by an order of magnitude, what would the ecological return on that investment be? Our ability to answer that question is limited by a lack of understanding of how much mortality actually occurs in the estuary, plume, and nearshore. Still, we do have some information about potential gains that reasonably could be expected as a result of such a large investment.

Juvenile Survival Improvement. In Chapter 5, survival improvement targets were developed as a tool for comparing the potential benefits of implementing different management actions. This planning exercise used the best available information about estuary mortality for wild, ESA-listed stream- and ocean-type juveniles and then established a 20 percent survival improvement target for the 22 management actions. The survival improvement targets were then allocated across the various management actions to help characterize where survival gains might occur. The results are conjecture and are not intended to represent a deterministically based analysis; however, the numbers do reflect information in the scientific literature, especially about mortality resulting from terns, cormorants, ship wake stranding, contaminants, and pinnipeds.

Tables 7-2 and 7-3 summarize the results of this planning exercising, sorting actions by their potential to improve survival of stream- and ocean-type juveniles, respectively, assuming that implementation of the actions is constrained. This ordering is simply an exercise to hypothesize where survival improvements equal to 20 percent of the number of juveniles exiting the estuary and plume might be expected for stream-type salmonids and ocean-type juveniles.

For stream-type salmonids, the following observations can be made from Table 7-2:

- Approximately 60 percent of the survival improvements are assigned to the top five actions, which include adjusting flow, restoration of contaminated sites, and managing birds and fish that prey on salmonids.
- Approximately 30 percent of the survival improvements are assigned to breaching levees, protecting off-channel habitat and riparian areas, reducing sources of pollutants, and removing pilings and pile dikes.
- Approximately 10 percent of the survival improvements are assigned across the remaining actions, with varying degrees of improvements.

For ocean-type salmonids, the following observations can be made from Table 7-3:

- Approximately 65 percent of the survival improvements are assigned to the top five actions, which include adjusting flows, breaching and lowering dikes, protecting remaining off-channel habitat, and addressing issues of contamination.
- Approximately 25 percent of the survival improvements are assigned to protecting and restoring riparian areas, reducing reservoir heating, removing pilings and pile dikes, reducing vessel wake stranding, implementing pesticide and fertilizer BMPs, and managing piscivorous fish.
- Approximately 10 percent of the survival improvements are assigned across the remaining actions, with varying degrees of improvements.

TABLE 7-2
Management Actions Sorted by Benefit to Stream-type Juveniles

#	Action	Survival Target (Stream Types)	Percentage of Target Improvements
CRE-16	Redistribute Caspian terns.	350,000	~60%
CRE-17	Redistribute cormorants.	250,000	
CRE-04	Adjust the timing, magnitude, and frequency of flows.	150,000	
CRE-22	Monitor and restore contaminated sites.	150,000	
CRE-13	Manage pikeminnow and other piscivorous fish.	125,000	
CRE-08	Remove pilings and pile dikes.	115,000	~30%
CRE-10	Breach or lower dikes and levees.	100,000	
CRE-01	Protect/restore riparian areas.	100,000	
CRE-09	Protect remaining high-quality off-channel habitat.	100,000	
CRE-21	Identify and reduce sources of pollutants.	72,000	
CRE-20	Implement pesticide/fertilizer BMPs.	44,000	~10%
CRE-02	Operate the hydrosystem to reduce reservoir heating.	30,000	
CRE-03	Establish minimum instream flows.	20,000	
CRE-15	Reduce noxious weeds.	15,000	
CRE-23	Implement stormwater BMPs.	15,000	
CRE-06	Use dredged materials beneficially	15,000	
CRE-07	Reduce entrainment/habitat effects of dredging.	10,000	
CRE-05	Mitigate entrapment of fine sediment in reservoirs.	5,000	
CRE-11	Reduce over-water structures.	5,000	
CRE-18	Reduce shad abundance.	5,000	
CRE-19	Prevent invertebrate introductions.	2,000	
CRE-12	Reduce vessel wake stranding.	2,000	
	Total:	1.68 million	

TABLE 7-3
Management Actions Sorted by Benefit to Ocean-type Juveniles

#	Action	Survival Target (Ocean Types)	Percentage of Target Improvements
CRE-10	Breach or lower dikes and levees.	450,000	~65%
CRE-09	Protect remaining high-quality off-channel habitat.	350,000	
CRE-22	Monitor and restore contaminated sites.	300,000	
CRE-21	Identify and reduce sources of pollutants.	275,000	
CRE-04	Adjust the timing, magnitude, and frequency of flows.	250,000	
CRE-08	Remove pilings and pile dikes.	175,000	~25%
CRE-01	Protect/restore riparian areas.	150,000	
CRE-13	Manage pikeminnow and other piscivorous fish.	140,000	
CRE-02	Operate the hydrosystem to reduce reservoir heating.	100,000	
CRE-12	Reduce vessel wake stranding.	55,000	
CRE-20	Implement pesticide/fertilizer BMPs.	55,000	
CRE-06	Use dredged materials beneficially	50,000	~10%
CRE-23	Implement stormwater BMPs.	45,000	
CRE-11	Reduce over-water structures.	30,000	
CRE-03	Establish minimum instream flows.	25,000	
CRE-15	Reduce noxious weeds.	20,000	
CRE-07	Reduce entrainment/habitat effects of dredging.	8,000	
CRE-19	Prevent invertebrate introductions.	8,000	
CRE-05	Mitigate entrapment of fine sediment in reservoirs.	5,000	
CRE-18	Reduce shad abundance.	5,000	
CRE-16	Redistribute Caspian terns.	2,000	
CRE-17	Redistribute cormorants.	2,000	
	Total:	2.5 million	

While many of the actions are highly constrained, the planning exercise summarized in Tables 7-2 and 7-3 assumes that, even with incremental changes associated with constrained implementation, certain actions could yield significant results, especially when coupled with complementary actions. For example, ocean-type juveniles rely heavily on off-channel habitats for food sources and rearing opportunities. The two primary actions intended to improve access to off-channel habitats are CRE-10, "Breach or lower dikes and levees," and CRE-4, "Adjust the timing, magnitude, and frequency of flows." Implementation of both of these actions is highly constrained, yet they could have synergistic effects and their joint implementation—even if only partial—could result in significant survival improvements for ocean-type salmonids. In contrast, if only one of these actions were implemented (or, worse yet, neither), other actions would need to be implemented as fully as possible in an attempt to compensate for the foregone opportunity to address one of the main factors limiting juvenile salmonid performance in the estuary.

Adult Survival Improvement. Because CRE-14, "Reduce predation by pinnipeds," is the only action that directly addresses the adult life history stage of salmonids, this action is treated separately and is not included in Tables 7-2 and 7-3. Pinniped predation on spring chinook and steelhead (both stream types) at Bonneville Dam has been estimated to be approximately 3.4 percent of the salmonids arriving at the dam (U.S. Army Corps of Engineers 2006). Estimates of downstream mortality from Stellar and California sea lions have not been published, but unsubstantiated estimates of mortality are more than 10 percent. If applied to 2005 run returns, this rate of predation would equal about 29,000 adult spring chinook and winter steelhead (includes ESA-listed and non-listed adults). Projects to reduce pinniped predation have had limited success, and more stringent management techniques are constrained by protections afforded by the Marine Mammal Protection Act. Although the act does provide for lethal control, the process for implementing that provision is formidable. Given these constraints, CRE-14 is assigned a 17 percent reduction (approximately 5,000 fish) in pinniped-related mortality of stream-type adults annually. This is a target only and should be considered a starting place for public decision making.

Costs for Constrained Implementation of Management Actions

Estimating the cost of constrained implementation of actions is inherently speculative. This is because in many cases, the constraints to implementation have not yet been explored in enough detail to be able to determine what is and is not possible. In Chapter 5, Table 5-6 established a level-of-effort budget estimate for partial implementation of actions by assuming an optimistic view—that constraints can be reduced through focused effort and that positive changes in the estuary can be made. A more pessimistic view would likely yield a significantly lower cost estimate, with correspondingly smaller survival improvements. Costs were assigned at the project scale to help identify possible components to actions, with the expectation that future refinements would yield a more sophisticated estimate. Finally, project costs were estimated over a 25-year time horizon.

Table 7-4 organizes management actions by total estimated cost (from Table 5-6). The following observations can be made:

- Costs for the top six actions total $320 million, or about 62 percent of the entire budget. The actions include restoring contaminated sites, modifying flows, reducing sources of pollutants, breaching or lowering dikes and levees, protecting off-channel habitats, and protecting and restoring riparian areas.

- Costs for the next five actions on the list equal $96 million, or about 19 percent of the budget. This group of actions consists of reducing reservoir-related temperature changes, reducing noxious weeds, addressing vessel wake stranding, removing pilings and pile dikes, and managing fish that prey on salmonids.
- The final 12 actions on the list equal $98 million, or about 19 percent of the budget.

TABLE 7-4
Management Actions Sorted by Estimated Cost

#	Action	Cost of Action	Cost per Group of Actions
CRE-10	Breach or lower dikes and levees.	$75 million	~$320 million, or 62% of total
CRE-22	Monitor and/or restore contaminated sites.	$60.5 million	
CRE-09	Protect remaining high-quality off-channel habitat.	$53.75 million	
CRE-21	Identify and reduce sources of pollutants.	$51.2 million	
CRE-04	Adjust the timing, magnitude, and frequency of flows.	$44.5 million	
CRE-01	Protect/restore riparian areas.	$35 million	
CRE-08	Remove pilings and pile dikes.	$30.5 million	~$96 million, or 19% of total
CRE-02	Operate the hydrosystem to reduce reservoir heating.	$20 million	
CRE-15	Reduce noxious weeds.	$15.5 million	
CRE-13	Manage pikeminnow and other piscivorous fish.	$15.05 million	
CRE-12	Reduce vessel wake stranding.	$15 million	
CRE-14	Reduce predation by pinnipeds.	$14 million	~$98 million, or 19% of total
CRE-17	Redistribute cormorants.	$12 million	
CRE-20	Implement pesticide/fertilizer BMPs.	$12 million	
CRE-03	Establish minimum instream flows.	$10 million	
CRE-16	Redistribute Caspian terns.	$10 million	
CRE-23	Implement stormwater BMPs.	$8 million	
CRE-05	Mitigate entrapment of fine sediment in reservoirs.	$8 million	
CRE-06	Use dredged materials beneficially.	$6 million	
CRE-11	Reduce over-water structures.	$5.8 million	
CRE-18	Reduce shad abundance.	$5.5 million	
CRE-07	Reduce entrainment/habitat effects of dredging.	$4 million	
CRE-19	Prevent invertebrate introductions.	$3 million	
	Total:	$514.3 million	

There is significant uncertainty in these cost estimates because of the ambiguity about the degree to which constraints to implementation can be overcome and the level of effort that would be required to achieve a measurable result. However, it is assumed that if restoring the ecosystem of the Columbia River estuary were established as a goal, this would require financial investment on a par with that for other major ecosystem recovery efforts around the United States. Such an investment would likely exceed the $500 million cost estimate in the recovery module, over a much longer period of time—up to 50 years or more.

Cost-Effectiveness of Management Actions

Cost-effectiveness is an important consideration when attempting to achieve large goals with limited resources, and the more limited the resources with respect to the goal, the more important it is that the maximum benefit be obtained from each expenditure. In the case of the Columbia River estuary, improving conditions for salmonids is likely to be an expensive and long-term effort—one that will require careful consideration of the survival benefits and costs of possible actions.

The linkage between the survival benefits and costs in this recovery plan module is difficult to characterize accurately because of the margin of error that, at this point, exists in both the estimated costs and the survival targets. Because the survival improvement targets were allocated across the set of actions as a planning exercise rather than as results of a scientific analysis, it is the allocation that is most important, not the numbers themselves. In the case of costs, estimates were made assuming that constraints to implementation of actions could be partially overcome; this assumption served as a way to explore the degree of constraints and the level of effort that would be required to bring about significant benefits to salmonids. The resulting costs should be viewed as preliminary numbers useful in starting critical discussions about decisions that will shape the future of the estuary and, to some degree, the region.

Understanding that, as outlined above, there are limitations governing the survival improvement targets and cost estimates, these sets of numbers can be compared to provide clues about which management actions might be the most cost-effective. Table 7-5 makes such a comparison, using cost information from Table 7-4 and target survival improvements from Table 7-3 to estimate the cost-effectiveness of each action, expressed as a cost/survival index. The actions are sorted in ascending order to show the most cost-effective actions first.

Table 7-5 is intended only as a general indication of cost-effectiveness, with the numbers in the table useful only in helping to frame the discussion about implementing management actions. Also, some actions were assigned very conservative survival improvement numbers because of the level of uncertainty about underlying ecological processes. This is the case with several actions related to the food web because the connection between food web changes and effects on juveniles is unclear. As a result, the cost-effectiveness ratings of these actions appear unrealistically high.

TABLE 7-5
Management Actions Sorted by Cost/Survival Index

#	Action	Survival (Ocean Types)	Survival (Stream Types)	Total Survival	Cost of Action	Cost/ Survival Index
CRE-16	Redistribute Caspian terns.	2,000	350,000	352,000	$10 million	28
CRE-17	Redistribute cormorants.	2,000	250,000	252,000	$12 million	48
CRE-13	Manage pikeminnow and other piscivorous fish.	140,000	125,000	265,000	$15.05 million	57
CRE-06	Use dredged materials beneficially.	50,000	15,000	65,000	$6 million	92
CRE-08	Remove pilings and pile dikes.	175,000	115,000	290,000	$30.5 million	105
CRE-04	Adjust the timing, magnitude, and frequency of flows.	250,000	150,000	400,000	$44.5 million	111
CRE-09	Protect remaining high-quality off-channel habitat.	350,000	100,000	450,000	$53.75 million	119
CRE-20	Implement pesticide/fertilizer BMPs.	55,000	44,000	99,000	$12 million	121
CRE-23	Implement stormwater BMPs.	45,000	15,000	60,000	$8 million	133
CRE-22	Monitor and/or restore contaminated sites.	300,000	150,000	450,000	$60.5 million	134
CRE-10	Breach or lower dikes and levees.	450,000	100,000	550,000	$75 million	136
CRE-01	Protect/restore riparian areas.	150,000	100,000	250,000	$35 million	140
CRE-21	Identify and reduce sources of pollutants.	275,000	72,000	347,000	$51.2 million	148
CRE-02	Operate the hydrosystem to reduce reservoir heating.	100,000	30,000	130,000	$20 million	154
CRE-11	Reduce over-water structures.	30,000	5,000	35,000	$5.8 million	166
CRE-03	Establish minimum instream flows.	25,000	20,000	45,000	$10 million	222
CRE-07	Reduce entrainment/habitat effects of dredging.	8,000	10,000	18,000	$4 million	222
CRE-12	Reduce vessel wake stranding.	55,000	2,000	57,000	$15 million	263
CRE-19	Prevent invertebrate introductions.	8,000	2,000	10,000	$3 million	300
CRE-15	Reduce noxious weeds.	20,000	15,000	35,000	$15.5 million	443
CRE-18	Reduce shad abundance.	5,000	5,000	10,000	$5.5 million	550
CRE-05	Mitigate entrapment of fine sediment in reservoirs.	5,000	5,000	10,000	$8 million	800

The following observations can be made from Table 7-5:

- The median of all assigned cost/survival index numbers is 138. (The median is the middle number of a group of numbers, with half the numbers having values greater than the median and half having values less than the median).
- Some of the actions that appeared most cost-prohibitive in Table 7-4, such as breaching or lowering dikes and levees (CRE-10), adjusting flows (CRE-04), and monitoring and/or restoring contaminated sites (CRE-22), emerge as cost-effective when viewed in the context of the survival improvements they could bring about. All three of these actions have a cost/survival index value that is less than the median and that puts them in the top—or more cost-effective—half of Table 7-5.
- Several actions, including redistributing terns (CRE-16), redistributing cormorants (CRE-17), and managing piscivorous fish such as pikeminnow (CRE-13), appear to be very cost-effective.

In this planning exercise, the total survival improvement of actions listed above the median is 3.2 million juveniles (1.8 million ocean type and 1.4 million stream type), or about 17 percent of the total number of juveniles currently thought to be exiting the estuary.

Improving Ecosystem Health

The Columbia River estuary, plume, and nearshore ecosystems are degraded compared to historical conditions. One hypothesis of this recovery plan module is that if the estuary, plume, and nearshore remain in their degraded state, recovery of all 13 ESUs may not be possible. Although this hypothesis is untested, it certainly is within the realm of possibility given what is known about the mortality of salmonids in the estuary as a result of certain threats, such as Caspian terns, double-crested cormorants, and contaminants. Until this hypothesis is disproved, it would be prudent to assume that successful basinwide recovery efforts will require improvements in the health of the estuary ecosystem. The remainder of this section is intended to help characterize choices that will ultimately govern the health of the estuarine ecosystem in the Columbia River.

Is there really a problem for salmonids in the estuary? LCFRB (2004), sources such as *Salmon at River's End* (Bottom et al. 2005), and emerging micro-acoustic tagging studies make clear that the mortality rate in the estuary is very high and almost certainly approaches 50 percent for some ESUs. This alone argues for discarding the old paradigm of the estuary as primarily a transportation corridor for salmonids on their journey to the ocean. Stream- and ocean-type salmonids clearly rely on estuary, plume, and nearshore habitats for crucial rearing and refuge opportunities during one of the stages in their life cycles, and Chapters 3 and 4 of this estuary recovery module describe the mechanisms by which a degraded estuarine ecosystem puts juvenile salmonids at risk.

Is ecosystem restoration necessary in the estuary, or can we surgically reduce specific threats to improve salmonid survival? Ecosystem health in the estuary, plume, and nearshore is the cumulative result of many stressors that originate within the estuary and also outside of the estuary. The level of constraint observed in each of the management actions identified in this estuary recovery module is high, and it is extremely unlikely that one or more actions could be implemented to the degree that they would essentially eliminate a threat to salmonids. Thus each management action should be implemented to the greatest degree practical, unless it is proven that to do so would seriously undermine public safety, the economy, or property rights.

What suite of actions is most important to implement for ocean-type salmonids? There is no single correct answer to this question. In the long term, ecosystem restoration will provide the most stable, self-supporting conditions for salmonids and other native species. Ocean-type juvenile salmonids rear longer in the estuary than stream types do and therefore would benefit the most from improved ecosystem health.

The analysis and planning exercises in this recovery plan module suggest that the most important actions for ocean-type salmonids are the following:

- CRE-01: Protect/restore riparian areas.
- CRE-02: Operate the hydrosystem to reduce reservoir heating.
- CRE-04: Adjust the timing, magnitude, and frequency of flows.
- CRE-08: Remove pilings and pile dikes.
- CRE-09: Protect remaining high-quality off-channel habitat.
- CRE-10: Breach or lower dikes and levees.
- CRE-13: Manage pikeminnow and other piscivorous fish.
- CRE-21: Identify and reduce sources of pollutants.
- CRE-22: Monitor and restore contaminated sites.

Implementing this suite of actions would cost approximately $385.5 million and would be expected to yield survival improvements of roughly 2.2 million wild, ESA-listed ocean-type juveniles, or 88 percent of the survival target for ocean-type salmonids. In other words, for ocean-type juveniles, 88 percent of the gain to be had from the management actions could be achieved by implementing these nine actions.

What suite of actions is most important to implement for stream-type salmonids? Stream-type salmonids prefer deeper waters with higher velocities than ocean-types do. They also reside in the estuary for shorter periods of time, but they tend to use the plume more extensively than do ocean-type salmonids. Stream-type juveniles are thought to actively feed in the estuary; new information indicates that stream types travel out of the channel to forage and may encounter predators such as the northern pikeminnow (Casillas 2006). For stream types, it is very important to reduce Caspian tern and double-crested cormorant predation. In addition, predation by pinnipeds on adult spring chinook and winter steelhead is a significant threat.

The analysis and planning exercises in this recovery plan module suggest that the most important actions for stream-type salmonids are the following:

- CRE-01: Protect/restore riparian areas.
- CRE-04: Adjust the timing, magnitude, and frequency of flows.
- CRE-08: Remove pilings and pile dikes.
- CRE-09: Protect remaining high-quality off-channel habitat.
- CRE-10: Breach or lower dikes and levees.
- CRE-13: Manage pikeminnow and other piscivorous fish.
- CRE-14: Reduce predation by pinnipeds.
- CRE-16: Redistribute Caspian terns.
- CRE-17: Redistribute cormorants.
- CRE-21: Identify and reduce sources of pollutants.
- CRE-22: Monitor and restore contaminated sites.

Implementing this suite of actions would cost approximately $401.5 million and would be expected to yield survival improvements of roughly 5,000 stream-type adults (ESA-listed and non-listed adults) and 1.51 million wild, ESA-listed stream-type juveniles, or 90 percent of the survival target for stream-type juveniles. In other words, for stream-type juveniles, 90 percent of the gain to be had from the management actions could be achieved by implementing these 11 actions.

How cost-effective are the top actions for ocean- and stream-type salmonids? Of the top 11 priority actions for stream- and ocean-type salmonids, nine are listed at or above the median cost/survival index.

What would be gained by implementing actions that benefit both ocean- and stream-type salmonids? The lists of priority actions identified above for ocean- and stream-type salmonids contain eight actions that are predicted to benefit both types of salmonids. These actions are as follows:

- CRE-01: Protect/restore riparian areas.
- CRE-04: Adjust the timing, magnitude, and frequency of flows.
- CRE-08: Remove pilings and pile dikes.
- CRE-09: Protect remaining high-quality off-channel habitat.
- CRE-10: Breach or lower dikes and levees.
- CRE-13: Manage pikeminnow and other piscivorous fish.
- CRE-21: Identify and reduce sources of pollutants.
- CRE-22: Monitor and restore contaminated sites.

Implementing this set of actions would cost approximately $365.5 million and would be expected to yield survival improvements of roughly 3 million wild, ESA-listed juvenile salmonids (ocean- and stream-types combined). Although the majority of these would be ocean types, there is an argument to be made for favoring actions that would benefit both salmonid types—namely, that implementing such actions would be likely to provide benefits across the spectrum of life history strategies that juvenile salmonids of both types employ in the estuary. Many of the actions that benefit stream-type salmonids would also benefit ocean types displaying less dominant life history strategies, while many actions benefiting ocean-type salmonids would also benefit stream types displaying less dominant life history strategies. Actions that benefit both ocean- and stream-types, then, presumably would affect a wide range of less dominant life history strategies and thus would help preserve the diversity that contributes to salmonids' ability to persist in the face of changing environmental conditions.

However, this is not to suggest implementation only of those actions that would benefit both ocean- and stream-type juveniles because there are limitations to this approach. For instance, avian and pinniped predation actions, which would primarily benefit stream types, are cost-effective and critical to improving the survival of stream-type salmonids.

What is the schedule or critical path for implementation of actions? Table 5-2 includes a rudimentary schedule for implementation of each management action. Schedule considerations in the table are based primarily on the specific action and the timing of its component projects that depend on other projects.

At this point in estuary recovery planning, developing a critical path for the implementation of actions collectively is premature. A more reliable and refined schedule would require better understanding of the level of effort that will be applied to the estuary, and it is likely that such a schedule would correspond closely to different funding levels and key project dependencies. An important consideration concerning schedule and critical path is that it may take decades to produce measurable effects in ecosystem restoration; thus, as a schedule for implementing management actions is developed, strategies should be employed that consider short- and long-term results.

Who is responsible for recovery implementation and oversight? Implementation of the 23 actions will occur through a variety of federal, state, and local agencies, as well as non-profit organizations (such as watershed councils), private enterprises, and citizens. Some of these have been identified in Table 5-6. Several organizations have been working to identify and prioritize salmon and steelhead recovery projects in the estuary; these organizations include the Lower Columbia River Estuary Partnership, the Lower Columbia Fish Recovery Board, and watershed councils in Oregon. There also is a need for coordinated oversight and monitoring, data management, and adaptive management of salmon and steelhead recovery projects in the estuary. While some elements of these larger processes are in place, additional organizational capacity is necessary if these needs are to be adequately addressed.

What about the lower ranking actions? In many ways, the lower ranking actions are the most difficult to characterize in terms of survival improvements and costs. This means that low ratings may be due more to a lack of scientific information than a lack of effectiveness. For example, basic changes to the food web in the estuary as a result of reservoir phytoplankton production or the introduction of invertebrates may have profound effects on the estuary, but the degree of impact is unknown. These threats must be more fully understood if their contribution to overall ecosystem health is to be determined with accuracy.

Are there other implementation factors that should be considered? Many of the management actions could have far-reaching effects if they were implemented, either because they address multiple interrelated threats, such as flow regulation and impaired sediment transport, or because their effects could compound the benefits of other, complementary management actions. An example would be the two actions of improving flows and lowering dikes and levees. Although each action by itself would increase salmonid access to off-channel habitat, implementing both actions could offer exponentially greater access, as well as contribute macrodetrital inputs to the food web and offer other ecosystem benefits. Although such benefits are difficult to quantify, the potential for synergistic effects of complementary actions is real and should be taken into consideration when management actions are selected.

How can implementation of the management actions gain traction? Threats to salmonids in the estuary are likely to continue unabated unless resource users in the Columbia River basin make different choices about consumption and development—choices that may be socially and politically challenging. In the face of social and political obstacles, education is one way of garnering support for implementation of the management actions; in fact, education is likely to be essential if the full suite of actions is to be implemented as envisioned in the module. For this reason, many of the management actions include education about stewardship and the ecosystem benefits that implementation would provide. In the end, though, the degree of implementation will be determined by the social and political will of the region, and what current and future residents of the basin are willing to pay—or do without—in order to return salmon and steelhead to viable levels.

Preparation for Decision Making

Chapter 7 is intended to help organize a much-needed conversation about recovery efforts in the estuary, plume, nearshore, and other ecosystems that salmonids depend on to complete their life cycles. While there are many decisions to be made, perhaps the most important is what our level of effort and commitment will be to improving conditions in the estuary. This boils down to deciding how much we are willing to do to recover salmon and steelhead in the Columbia River basin and how comfortable we are with the sacrifices that will be necessary.

The planning exercises in Chapters 5 and 7 were based on the best available science pertaining to limiting factors and threats. However, although science can help inform the key analyses in these chapters (identification of management actions, constraints evaluation, target survival improvements, and cost estimates), it cannot tell us which management actions to implement. This is partly because of the gaps in our understanding of the physical and biological world of the estuary but also because other decision-making processes are at least as important as science when it comes to making choices about the future and what we most value.

Perhaps the single most important conclusion that can be made about the prioritization of management actions is that threats remain threats to salmonids because tough choices have yet to be made—choices that are difficult because of the myriad conflicting goals of the various public, private, individual, and organizational interests within the Columbia River basin. The variety and extent of those interests are reflected in the high degree of constraint for each of the 23 management actions identified in the recovery plan module. The take-home message from this is that the estuary, plume, and nearshore are crucial to ocean- and stream-type salmonids and that achieving a meaningful boost in survival from these ecosystems will require a major investment and implementation of all 23 management actions, to the extent possible.